1981

Air Conditioning without Air Conditioners

As the green tide of spring spreads slowly north, people's thoughts turn from staying warm to keeping cool in the hot summer days ahead. For many the rites of summer begin with the ritual Uncovering and Cleanup of the Air Conditioner, followed by the Setting of the Thermostat and the Plugging-In. After duly initiating the cooling season, the attention shifts to chaise lounges or lawn mowers, or to any number of repairs to the ravages of winter. The cooling system will be left to defend the house against oppressive heat and humidity, and it will run and run and run as long as it takes to get the job done. It gets expensive. In many parts of the country a summer's worth of cooling with an air conditioner is more expensive than winter space heating, but there are all kinds of techniques for house cooling that don't involve a single kilowatt-hour. When more cooling is needed, low-power fans are used instead of power-hungry air conditioners. In this essay we'll follow two basic themes of natural cooling. The first is reducing the amount of summer heat that gets into a house, and the second is providing additional interior cooling when heat gain can't be adequately resisted. By implementing some of these methods, you may be able to give your air conditioner a summer vacation instead of a summer job.

In the previous two sections we've presented all sorts of ways to add solar space heating, but it's important to keep in mind the need for cooling because increased solar heating capability can easily contribute to an increased cooling load. The area of your solar glazing should be tuned to the actual heating demand and not just expanded to cover all the available solar surfaces. To prevent summer heat buildup from direct, reflected and diffuse gains, space heating systems should be designed to vent solar-heated air directly to the outside and/or to block solar gain with overhangs, awnings, landscape shading and other shading techniques.

There are also simple management techniques, such as controlling windows, that you employ without making any drastic changes. Building insulation is another friend of natural cooling. In summer the heat source is of course outside the house, and insulation can greatly reduce conductive heat gain through walls, roofs and windows. In some areas, natural convection or fan-powered ventilation with cool night air, in conjunction with heat-gain reduction, can provide all of the cooling necessary for an energy-efficient house. If these techniques don't give you enough cooling comfort, there are ways to minimize the energy used by air conditioners. There is also something called an evaporative cooler, which uses less power than most air conditioners.

As you read, keep in mind the information on human comfort presented in "The Sun in Your Place" in Section I. Keeping cool doesn't necessarily mean keeping the air temperature at 72°F (22°C) or even 78°F (26°C), but involves the relationship between air temperature, humidity, air movement and mean radiant temperature (the temperature of surrounding surfaces), as well as the nature of your own indoor activities. Many of the techniques described here increase comfort by increasing air movement or reducing the mean radiant temperature and not just by reducing air temperature. With a lower mean radiant temperature, drier air and a gentle breeze, even at 84°F (29°C) you can feel comfortable.

Hot Weather House Management

Before you try cooling techniques that require major modifications, see what you can do to reduce the cooling load in your house just as it is. You may find that with wise management you can somewhat reduce the cooling load without any need for major changes. The most effective of these procedures involve controlling solar gain, ventilation cooling and minimizing interior production (internal gains).

Ventilation can provide the most powerful cooling in many cases. When the night air temperature drops, open windows and doors to let breezes cool the inside. This coolness or "coolth" is stored by the interior mass of the house (Sheetrock, tile floors, etc.). If there isn't much breeze, ventilation can be increased by using fans, the fan on an air conditioner or the furnace blower in the duct system if there is a "fan only" setting.

Ventilation helps not only by cooling the inside of the house but also by increasing the sweat evaporation rate from your skin and thus your sense of comfort. For example, a small, quiet portable fan in the bedroom can be aimed to blow over you while you sleep.

Solar heat gain through windows and sliding glass doors can be significantly reduced if the drapes, shades or blinds are closed when the sun is shining on them. Most effective are light-colored, opaque and insulated drapes and blinds. For maximum protection they should be well sealed at the top (with a valance), bottom and sides. If they don't have a sealed valance at the top, studies have shown that window coverings can actually increase heat gain by setting up a convective loop in which heat that builds up between window and shade is transferred to the room.[1]

Curtains and shades are often inset in the window frame, and in that location good side and bottom seals can be developed. Drapes, blinds or shades on east windows should be closed in the early morning; windows should be covered by mid-morning, and west windows should be shaded by early afternoon. If it is very hot and bright or if everyone is away during the day, close all the drapes, blinds and shades first thing in the morning and later open only the south and east ones in the evening, until the sun sets. (You might recall this is the exact opposite of the winter routine when you open the drapes on the east in the morning, south at midday, and west in the afternoon.) The savings from this simple activity can be significant. Studies made in Davis, California, have shown that interior shades can reduce room temperature 16°F (9°C) or more below that of a room with bare windows,[2] while another study at the Illinois Institute of Technology found that plain white roller shades could reduce total heat gain through the

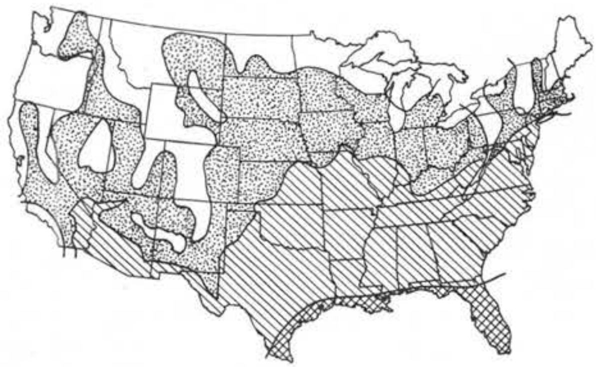

Figure V-1: This map shows some of the cooling strategies that can be used in different climate zones.

window by nearly 50 percent.[3] For very hot rooms, putting aluminum foil on the glass will make an even bigger difference.

Internal heat gain—the heat generated by people, lights and appliances—can make a significant contribution to an increased cooling load. Again, tailoring your household activities to be compatible with the season, and careful use of electrical equipment (lights, appliances) will limit this gain. Rather than baking or cooking meals that require use of the oven or range burners, create meals that can be prepared with no cooking or at least a minimum of stove "on time." If you are reaping a steady supply of fresh fruits and vegetables from your garden, you have the foundation for superb summer meals that don't need heat. Low-energy meals also reduce the electric or gas bill. If you do use the stove top or oven, plan to use it at night, if you can, so the added heat can be carried off by the night breezes and ventilation. Save the fancy cooking for winter when every bit of the added heat can be put to use.

The refrigerator and freezer both give off heat. If you can, put the freezer in the garage or in a room that can be closed, although some freezers can malfunction if they're kept in unheated spaces, and the manufacturer's warranty might be voided, so look over your owner's manual. Generally speaking, refrigerators and freezers should not be put in unheated rooms that drop below freezing. You can also help these appliances operate more efficiently by moving them a little farther from the wall, keeping the coils clean and opening them as little as possible. When you replace a freezer or refrigerator, get an energy-efficient one and buy the smallest unit that will meet your needs. The most efficient refrigerators use as little as 50 KWH of electricity per month instead of the norm of 200 to 300 KWH.

If you have the space, consider drying your clothes on a clothesline in the summer instead of in the dryer—reducing the cooling load of the house and saving the energy that the vacationing dryer doesn't use. If you must use the dryer, make sure it's properly vented to the outside with dryer vent hose to avoid the discomfort of added summertime humidity. Spending time outside while the weather's fine will also reduce heat gain from people, the tv, stereo and lights that you might otherwise use inside. Just by properly managing your house, you can greatly reduce the need for air conditioner cooling. You can go a lot further with natural cooling, however, by employing some or all of the following options.

Solar Control

In the broadest sense, solar control is a year-round practice, and most of this book is devoted to controlling solar heat in cold weather. But the sun, which provides such excellent heating in winter, becomes an unwelcome visitor in the summer. By using the appropriate solar controls you can block the summer sun yet still allow solar access for winter heating. Solar control for cooling relies on factors that are equally common to solar heating: orientation, shading, insulation, color and material, and landscaping.

Orientation

Your home's shape and orientation will play a vital role in summer heat gain and the ease of solar control. As you learned in the introduction, the best orientation for solar heating is with a rectangular house with its longest dimension facing due south and containing most of the windows. The north side should have the fewest windows. This shape will also stay coolest in the summer and is most amenable for solar control techniques (see table V-1).[4] However, a poorly oriented house offers the greatest room for improvement because it is so vulnerable to heat gains, so even if you have a tall house facing west, don't despair; there is much you can do to keep cool no matter what the building shape.

The sun rises a little north of east in summer; by noon it is very high in the sky and in the evening it sets to the north of west. During a summer day the sun's energy is concentrated on the east and west walls and windows while the south and north receive considerably less. Tables V-2 and V-3 show how significantly exposure or aspect is related to wall and window heat gain.

East and west windows receive almost twice the solar energy as do the south windows and nearly three times as much as the north windows. For walls, it's clear that increasing insulation has the greatest effect on reducing heat gain. The actual impact on your house will depend on its design and construction, local climate, and on the solar exposure of both the house and the site. The eastern sun may overheat the house early in the morning, requiring air conditioning all day. Or the house may be hit by the western sun in the afternoon, the warmest time of the day. The answer to most of these orientation-caused problems is solar control.

Insulated walls do much to resist conductive heat gain. Windows, on the other hand, provide little protection against conductive gain, but this isn't the primary concern with windows. Direct and diffuse radiation are by far the greatest contributors. Thus the first steps toward window control should be with shading, whether by overhangs, wing walls, exterior shades, interior drapes, blinds, shutters or tinted or reflective films.

TABLE V-1 COMPARISONS OF POTENTIAL SUMMER OVERHEATING FOR HOUSES OF DIFFERENT SHAPES AND ORIENTATIONS

Shape and Orientation	Interior Temperature (°F) Rise above Ambient
Dome	47
Tall broad model, east/west	47
Gable roof facing east/west	42
Cube facing northeast/southwest	36
Cube facing north/south	34
Two-story house facing north/south	26
Two-story white-roof house facing north/south	14

SOURCE: L.W. Neubauer, "Shapes and Orientations of Houses for Natural Cooling," *Transactions of the American Society of Agricultural Engineers,* vol. 15, no. 1 (1972), pp. 126–128.

NOTE: The models used in this study were closed, black metal boxes in order to standardize conditions. So when reading the numbers, it's important to bear in mind that people do not, of course, live in closed, black metal boxes. If all the above building shapes and orientations were part of real, open, well-insulated and ventilated houses, the temperature rise would be nowhere as great. These temperature data are used simply to show that certain building shapes are more liable than others to heat up.

TABLE V-2 SOLAR HEAT GAIN THROUGH WINDOWS AT 40° NORTH LATITUDE ON JUNE 21 (SOLSTICE)

Window Orientation	Btu/sf
N	484
NE, NW	894
E, W	1200
SE, SW	1007
S	622

SOURCE: American Society of Heating, Refrigerating and Airconditioning Engineers, *Handbook and Product Directory* (New York: ASHRAE, 1972).

TABLE V-3 SOLAR HEAT GAIN THROUGH SOLID WALLS AT 40° NORTH LATITUDE ON JULY 21 (AVERAGE AIR TEMPERATURE 83°F)

	Btu Gain per Square Foot of Wall Area			
Wall Orientation	8″ Brick, Uninsulated	Wood, Uninsulated Dark Paint	Wood, Uninsulated Light Paint	Wood, Insulated Dark Paint
N	760	380	367	190
NE, NW	820	410	384	205
E, W	864	432	393	216
SE, SW	855	427	388	214
S (shaded by overhang)	717	358	335	174

SOURCE: Clifford Strock and Richard Koral, eds., *The Handbook of Air Conditioning, Heating and Ventilating* (New York: Industrial Press, 1979).

Shading

The high angle of the summer sun makes the use of overhangs very attractive for solar control, particularly on a south wall. Extending the roof may not be cheap, but it is effective and permanent, while providing better weather protection for the south wall and windows. The required overhang extension for south windows depends on the months when shading is required, the height of the window and the latitude. Table V-4 provides a simple method for determining the needed overhang.

On some houses an overhang can be added along the south roof pitch simply by extending the rafters (by bolting extensions onto the rafter tails) and extending the roof. When planning such an extension, be aware of how low the new roof edge will be. You may want to build the extension at a slightly shallower pitch than that of the existing roof. If the total overhang can't be practically extended, or if you need to shade south windows on the first floor of a two-story building, you can build a simple overhang or add canvas or aluminum awnings. Beware of fixed awnings, however, because usually they're hung so low as to block direct gain in winter as well as in summer.

Unfortunately there is not a practical overhang design that works well for windows facing more than 15 to 20 degrees east or west of south. To be effective, an overhang for a 4-foot-high southeast window 1 foot below the eave would have to be 10 feet long to provide adequate protection. Wing walls or fins are effective in blocking gain into windows that face east or west of south. These "vertical overhangs" are extension partitions or "mini-walls" that can be made of materials identical or similar to the existing siding. They also can be made like attached fence sections with a light, airy appearance that won't dominate the appearance of the wall. In general practice, these wings are extended as far as overhangs.

Photo V-3: A simple and nice looking patio overhang greatly reduces the solar gain to the west wall of this house, and it keeps the patio a little cooler too. The slats could also be crisscrossed to increase the shading effect.

Table V-4 Finding the Overhang Required for Summer Shading

North Latitude	F factor*
28°	5.6–11.1
32°	4.0– 6.3
36°	3.0– 4.5
40°	2.5– 3.4
44°	2.0– 2.7
48°	1.7– 2.2
52°	1.5– 1.8
56°	1.3– 1.5

Horizontal extension of overhang = window height F

SOURCE: Edward Mazria, *The Passive Solar Energy Book* (Emmaus, Pa.: Rodale Press, 1979).

*Find the F factor in the table according to your latitude. The higher values will provide 100 percent shading at noon on June 21, the lower values until August 1.

To define an adequate degree of shading, it's helpful to use the term *shading coefficient* in describing the effectiveness of shading techniques on a numerical scale. A window fully exposed to the sun has a shading coefficient of 1 (maximum heat gain), while a window fully shaded by an overhang has a shading coefficient of 0.2. It is not 0 for an overhang because diffuse and reflected radiation can still get in. By contrast, an exterior vertical shade hung close to the window can have a shading coefficient as low as 0.1. The shading coefficient is a convenient way to compare the effectiveness of the different methods of solar control.

Windows that face east or west, or that face south with no overhang, may require exterior shading devices to provide an economical, attractive and effective means for shading them. Why not just use interior curtains or drapes you may ask? The answer is simple. Once the sun enters a window, heat has effectively entered the house, and although its impact can be reduced with an interior shade, some heat trapped between the shade and the window will still pass into the room. The simplest and cheapest method for exterior shading is often to hang a canvas or bamboo shade outside the window, supported by the roof overhang or an exterior valance. A space for venting should be

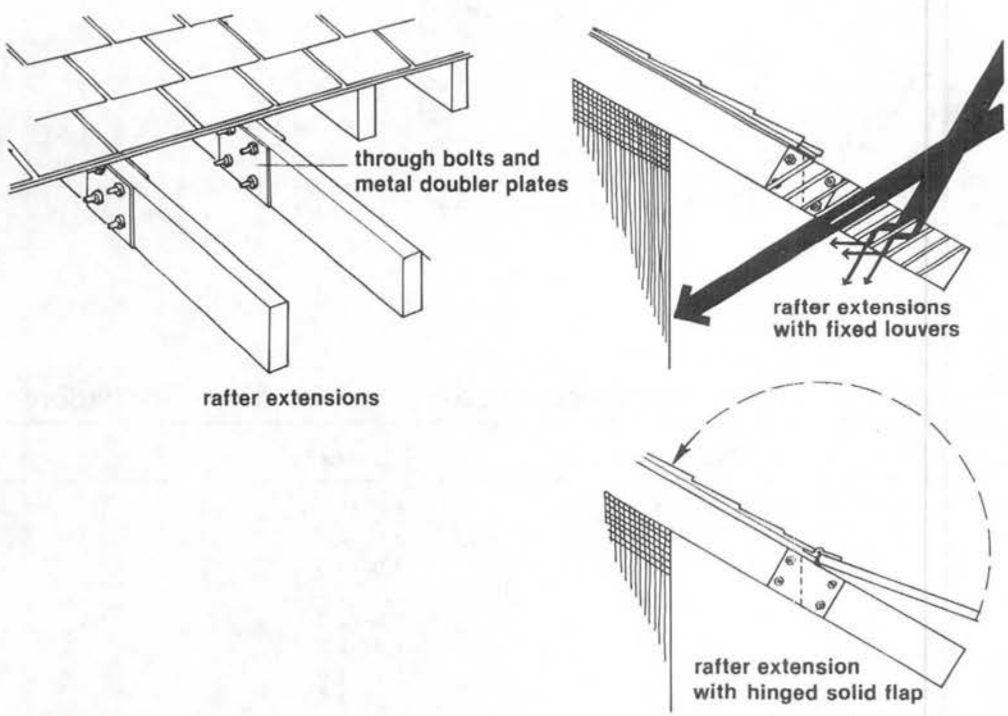

Figure V-2: Rafter extensions should be through-bolted to the existing rafter ends using doubler plates for maximum strength. Fixed louvers are one way to control solar gain in different seasons, while another possibility is to fasten a hinged panel to the extension. It can be put down onto the extension during warm weather.

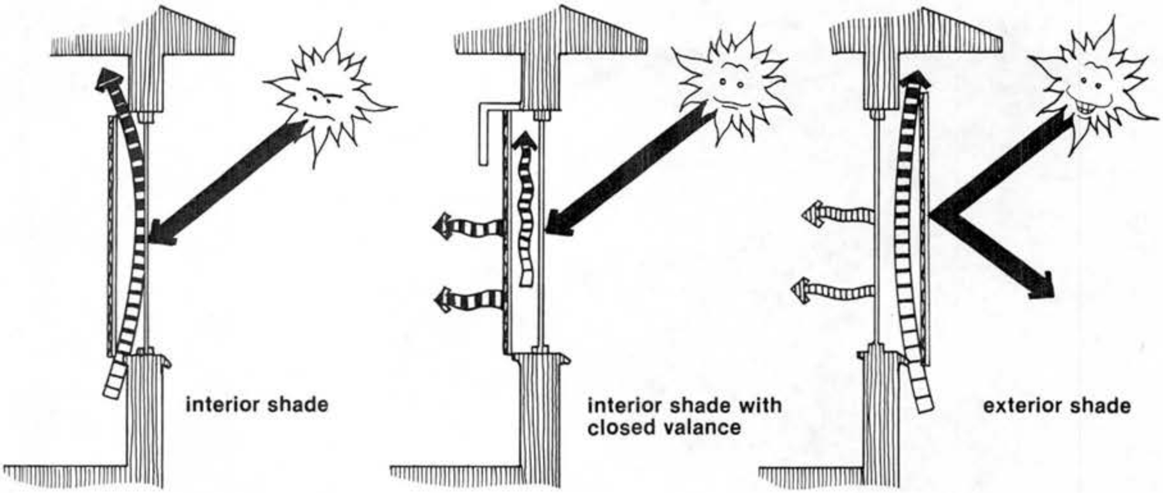

Figure V-3: As the illustration shows, exterior shading is the most effective for stopping heat gain. Most of the heat built up between the glazing and the shade convects away. The second best option is to have an interior curtain with a closed valance at the top to limit convective heat flow into the room.

left at the top of the support to prevent buildup of a pocket of hot air. This kind of system provides good protection for a modest investment. The shade can be rolled up in the evening and, when fall comes, it can be taken down and stored, just like the time-honored winter storm window routine. Where wind is a problem, it is necessary to provide a ground anchor, preferably with an elastic shock cord, to prevent flapping and possible damage to the shade.

Louvered shade screens can be a more expensive means of exterior shading than a roll-down awning, but they are also more convenient—no need to roll them up or down, and although they do have some filtering effect on incoming light, you can see through them clearly. Shade screen, which consists of many tiny louvers that also serve as an insect screen, can be used in standard screen frames that snap onto the windows. Several companies manufacture louvered metal shade screens with various louver angles and shading coefficients. (See the "Hardware Focus" section at the end of this essay.) The shading coefficient is typically about 0.2, the same as a full overhang. The two drawbacks are sensitivity to damage (kids, animals, low-hanging branches) and cost. Bronze shade screens, for example, can cost over $5 a square foot. They may be best used on east- and west-facing second-story windows that are removed from possible sources of damage.

More recently several companies have started manufacturing shade screens that use flat fiberglass webbing instead of louvers. This material is much cheaper (around $1 per square foot) and provides good shading (the shading coefficient is about 0.3). They are much more resistant to damage than metal shade screens, and they may be the best alternative in many cases. Naturally, both types of shade screens should be taken down

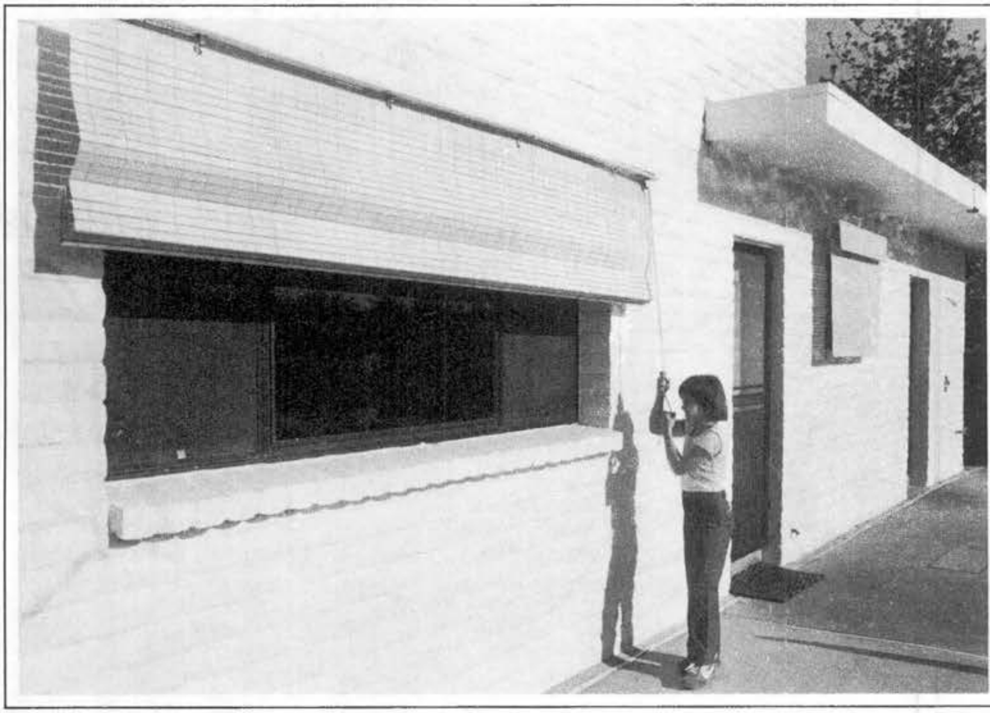

Photo V-4: Exterior shading for west- and east-facing walls is the most effective for reducing heat gain because it blocks sunlight before it passes through the window. Interior shades block sunlight effectively, but they can also trap heat between the shade and the window.

in the winter on south-facing windows to allow as much solar radiation to enter the house as possible.

Large louvers may also be used for a very effective and attractive fixed or movable exterior shade. Unfortunately, they are expensive unless you build them yourself. Vertical louvers are best when installed over east and west walls; horizontal louvers are best for the south. Shading coefficients of 0.2 to 0.3 are typical values for well-designed exterior louvers.

Freestanding walls and fences may also be used for exterior shading and can be particularly effective on the critical west windows and walls. They can also help prevent side yards or courtyards from becoming heat traps. They should be louvered or built with slats to reduce adverse effects of wind loading.

Is your porch rather furnacelike in summer? A roofed porch, particularly an east- or -west-facing one, can be shaded with homemade vertical sun screens that look quite nice. The screens are made up with a "weaving" of diagonally crisscrossed wood strips, e.g., plaster lath, set into a frame. These units can be installed permanently or seasonally; they'll still admit enough light so the porch won't be dull and dim.

The ultimate design of a total exterior shading retrofit may well include a mix

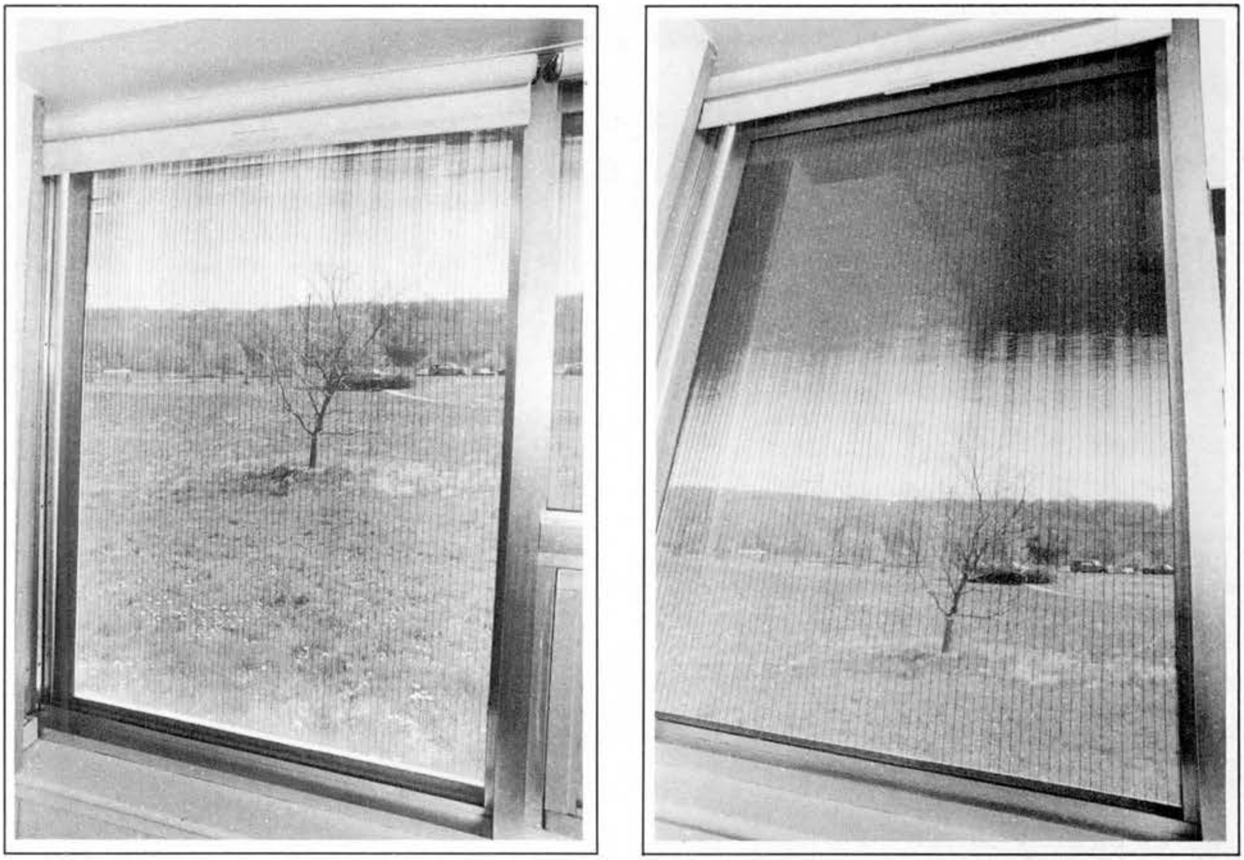

Photo V-5: Shade screens block sunlight, but they don't block the view. The photograph on the left shows the view through the screen at eye-level, while the one on the right shows how light is blocked when it comes in from a high (summer sun) angle.

of the options discussed here, depending on the many variables of orientation, window placement, available space (for wings and fences), and certainly on how the retrofits will affect your home's appearance.

Shading with Interior Drapes and Shutters

As noted, an interior shading device will do little to reduce heat gain unless it's sealed tightly to the window frame. If drapes, shades or shutters are well designed, however, they can provide effective control over direct gain and reduce conducted heat gain. To begin, however, let's consider their value for controlling direct gain.

The most common window fixtures are, of course, venetian blinds, roller shades and drapes. These standard items provide shading coefficients only one-half to one-fourth as effective as overhangs or exterior shading. A white curtain or roller shade has a value of 0.4, a white venetian blind about 0.6. Darker colored drapes, shades and venetian blinds may have a shading coefficient of only 0.7 to 0.8, hardly worth utilizing for sun control.

A much better alternative is offered by special drapes and interior shutters made specifically for solar control. These all include most of the following features: highly reflective outside material, high resistance to conductive heat flow (R-value about 5), and tightly sealed edges (top, bottom and sides). Properly made and installed, these units have a shading coefficient lower than an overhang—down to 0.1 or less—which makes them at least twice as effective at cutting out heat gain. However, for that level of efficiency they will admit little or no light unless a small opening is left in them. This kind of window treatment is a perfect example of how hot weather controls interface with cold weather controls. In cold weather the same insulated curtains or shutters can be used at night to reduce building heat loss through windows, making them an effective year-round energy control.

Nowadays an increasingly popular material for solar control is tinted or reflective film applied directly to the window glass or attached to a shade-roller mechanism. Although these are widely advertised as *the* solar control treatment for windows, they aren't always worthwhile, particularly for south-facing windows. The most obvious problem with fixed films is that they are permanent and cannot be removed in the winter. They are marginally effective for hot weather shading, with typical shading coefficients of only 0.3 to 0.5 and little resistance to conducted heat gain. For east- and west-facing windows these films can be helpful because overhang requirements are so great for those orientations. Use the darkest or most reflective films that provide a shading coefficient of at least 0.3.

Insulation and Building Color

Just as window insulation is a useful control in both hot and cold weather, so too is building insulation about as important in summer as it is in winter. The major source of summer heat gain in most houses is the roof, and roof or attic floor insulation is very helpful in minimizing the conduction of heat into attics and second-floor rooms, particularly on houses with dark-colored roofs.

Although insulated ceilings significantly reduce the interior heat gain from a hot roof, it is often desirable to further reduce gains with roof treatments such as light-colored roofing material to reflect rather than absorb solar energy. This change can reduce roof temperature by 50°F (28°C) or more,[5] keeping the house cooler and extending the life of the roof. Certain roofing materials also naturally "run" cooler than others. Wood shakes and shingles are particularly effective in this way, followed by tiles and light-colored asphalt shingles. On the other hand, tarred roofs, metal roofs and asphalt roll roofing are among the hottest.[6]

A design sometimes used in the tropics that may be desirable for reducing heat gains in very hot climates is the double roof. The upper roof membrane should be light

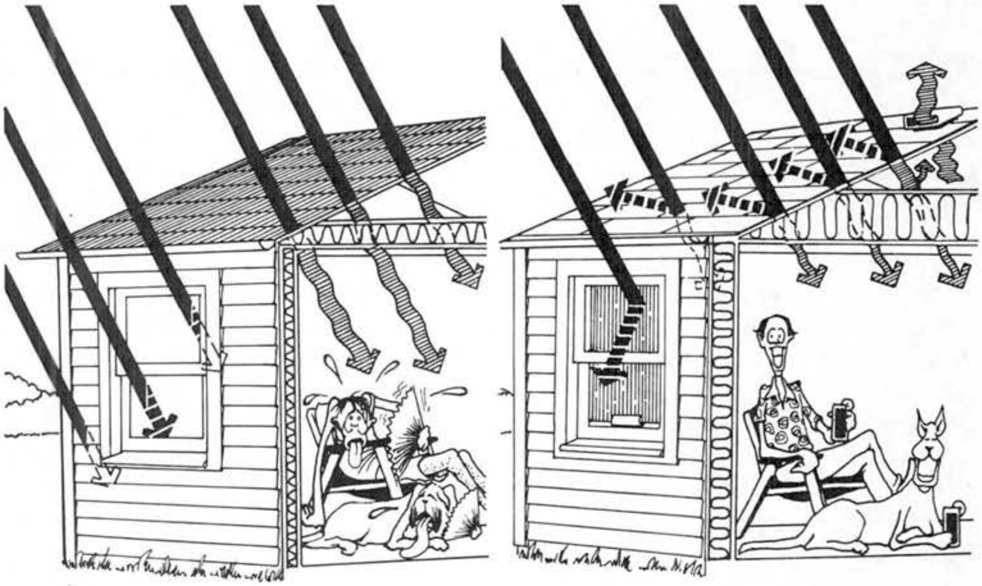

Figure V-4: By increasing building insulation, especially in the roof, you will minimize heat gain through the ceiling. The other treatments shown here are changing the roof material (when it's time to reroof) from a dark to a light color, increasing wall insulation and using window shades.

in color and thoroughly vented. The heat buildup between the two roofs sets up a convective air flow that exhausts hot air back to the atmosphere if the roofs are well-ventilated. This double roof idea meshes with another natural cooling option that uses the double roof at night to deliver cool air into the house. This is discussed shortly.

In a frame house the most critical walls vis à vis heat gain are the east and west walls, and they should be insulated and painted a light color (though you will certainly want to insulate all the walls to reduce cold-weather heat loss). If all the walls are massive (brick, cement, block, adobe or stone), exterior insulation and light color on the east, north and west walls would provide both summer and winter benefits by seasonally storing coolth in summer and heat in winter. Dark-colored massive south walls that are glazed over can capture the sun's energy and keep the house warm far into the night after outside air temperature has dipped below comfortable levels.

In fact, a stone, brick or concrete block building that has been covered with exterior insulation is likely to be a prime candidate for successful air conditioning without air conditioners, even in very hot climates. The large surface area of the mass walls helps keep the building cool by absorbing room heat. With vigorous nighttime ventilation, the cooling effect is enhanced even more, and those cool walls will be ready to absorb more heat during the following day. To overcome high interior temperatures, an evaporative cooler or air conditioner can be run during off-peak electrical use periods (night) to help the walls store additional coolth.

Landscaping

Proper placement of trees, vines and shrubs can provide very attractive and effective, but often overlooked, solar controls for roofs, walls and windows. Total shading from trees can have a shading coefficient of 0.2, the same as for an overhang! Properly placed deciduous trees will not block the winter sun if they are located mostly to the east and west of a building rather than directly to the south, where even bare branches might block valuable incoming winter sunlight. Deciduous trees are desirable for landscape shading because they automatically adjust for cool springs and hot falls. In early spring, the small leaves don't block much of the valuable sunlight, while in late fall the leaves will provide shade when there is still a need for cooling in many parts of the country. If a solid south overhang cannot practically be added, then landscape to provide needed shade on the large south windows. With an arbor, use a vine or plant that can be pruned back in the fall to allow nearly full sun through. Grapes, wisteria, morning glory and hops are all good candidates. Keep the structural members of the arbor as small as possible so they won't cast shadows in winter; wire works well, or you can make an arbor that is removable in winter.

The full landscape plan for a house might include: tall trees for roof shade, deciduous vines for shade on an arbor to the south of the windows, dark ground cover

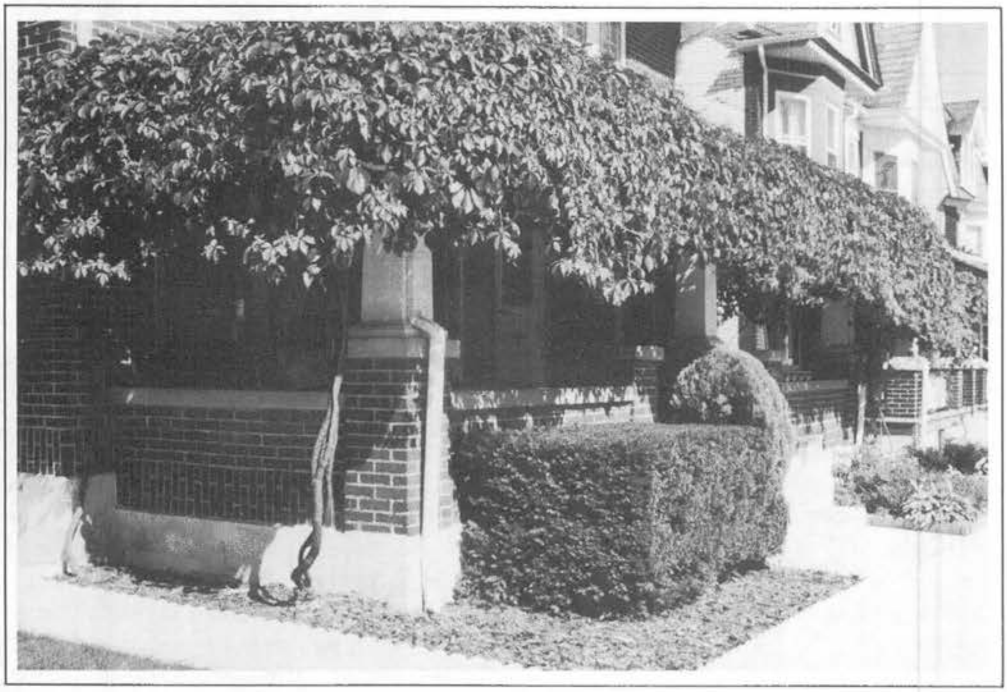

Photo V-6: These arbors are retrofits, of a few decades ago. The structure is formed of bent and straight pipe sections that are covered with a mesh that carries the grapevines.

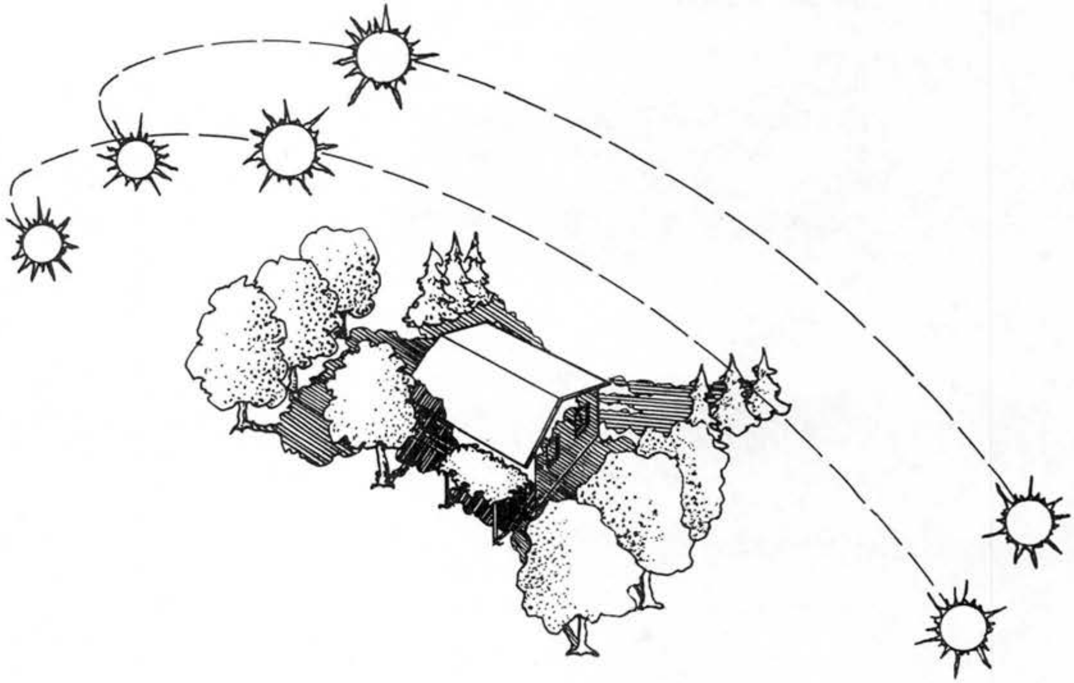

Figure V-5: This landscaping plan shows much use of deciduous trees for summer shading. Shadows cast on the ground as well as on the house itself help to cool the air around the house. Shady spots are also effective for evaporative cooling.

to the south to reduce ground reflection of light and heat, hedges to the east and west to shield the east and west walls and windows, and shrubs or small trees to the northeast and northwest to block late evening and early morning sun in the hottest period of the summer.

For even greater cooling, a hedge can be used as a living evaporative cooler. In Indio, California, a full hedge is laced along its top with a soaker hose that thoroughly wets the hedge. The evaporative cooling effect provides 10 to 15°F (6–8°C) cooler air for the patio and a cooler source of ventilation air for the house. Shaded, wet lawns can also contribute to a cooler building environment, especially compared to the way that concrete or gravel surfaces can heat up. Naturally, these methods work best in dry climates.

Not only does landscaping cool the house and yard, it also makes a quieter, cleaner and more satisfactory environment. In Sacramento, California, cutting down street trees in one neighborhood resulted in a 10°F jump in ambient summer air temperature and considerably increased cooling loads in adjacent homes.[7] Landscaping for cooling requires plenty of watering, trimming and leaf raking—but add up the energy, environmental and aesthetic benefits, and you've got a bargain in the making.

Ventilation

Ventilation with cool night air is a simple method of cooling, and it may be all that is required in many areas after the cooling load has been reduced as much as possible. By venting warm inside air and drawing in cooler night air, you can do much to keep a house cool during the day. As discussed earlier, natural ventilation with open windows and doors may provide sufficient cooling effect, but if it doesn't, you can modify the house to provide more effective ventilation by using the "thermal stack effect." Because of natural convection, warm air wants to rise, and when it does it is replaced by cooler air. The necessary modifications range from simply adding new operable windows or vents to more substantial changes that cause an increased rate of cooling air flow.

If natural convection ventilation proves insufficient, it may be desirable to use fan-powered ventilation with window fans or a forced-air duct system, or to add a whole-house fan. As you read through and evaluate the possibilities that can be applied to your house, keep in mind the two most common concerns with natural ventilation: security and allergies. Security can be maintained by installing stop locks and fixed or locked grilles, screens and vents, or by providing other blocks to open windows and large vents. Allergic reactions caused by the introduction of mold, fungi spores, pollen, dust or smog are best dealt with by using a filtered fan and by adding filters to intake vents.

In some areas, though, night ventilation will provide little benefit and may actually be undesirable. If the nighttime temperature doesn't drop below a dry 85°F (29°C), the best strategy is to put the most effort into resisting daytime heat gain. If the humidity is high with night temperatures remaining over 80°F (27°C), then night ventilation may not be as valuable as dehumidification. Much depends on the local climate and on the construction of your house and its inherent thermal performance.

To take an extreme case, if you live in an uninsulated house with a dark roof and the interior temperature at night is 95°F (35°C), then letting in even 90°F (32°C) outside air will be desirable (at least to help you be comfortable enough to think about adding insulation and light-colored roofing). On the other hand, if you've added exterior insulation to your concrete block house, painted the roof white and weatherized carefully, you're more in control of interior conditions. That's really the point of all energy upgrading—to gain control of outside conditions for both heating and cooling your home. Once you're in charge, common sense will most often tell you what to do.

Using Wind

Wind creates a zone of high pressure on the windward side of a house and a zone of low pressure on the leeward side. You can easily make use of these pressure differentials to cause air to flow through the house. There must of course be a cross flow since without an outlet the room is like a cave. Tests have shown that ventilation in a room with no outlet may be less than one-half that of a room with an inlet and an opposite-side outlet. For best wind flow through a building, provide an inlet and outlet

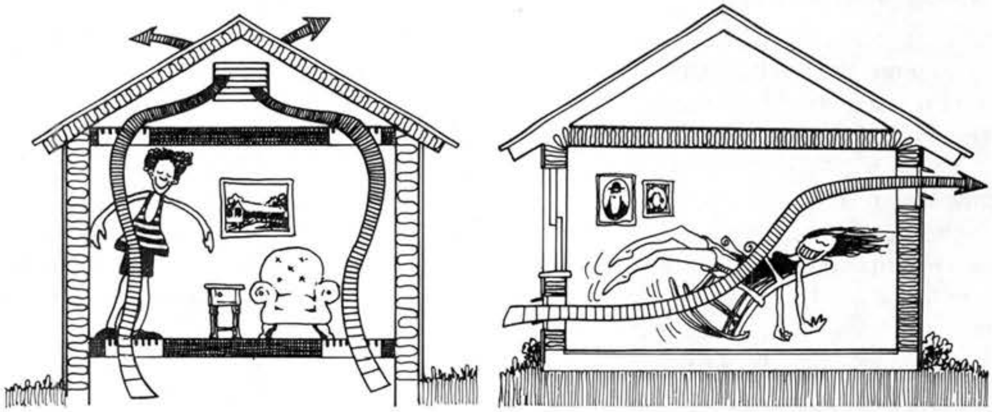

Figure V-6: Roof and wall vents will greatly improve ventilation cooling. On the left the floor registers are coupled to a cool basement or crawl space so that as the hot air leaves through the gable vent, cooler air is drawn in. At right an intake vent is placed in the path of the prevailing summer breezes, which can provide both ventilation and evaporative cooling effects.

in each room, and make the downwind outlet larger than the inlet. The wind flow will do the most good if it contacts people (evaporative cooling), so a low inlet vent coupled with a high outlet will maximize the cooling effect.

One of the simplest retrofits for improving natural ventilation is the addition of louvered vents or hinged panels either in partition walls or in or above interior doors that are kept closed at night. These vents should be sized approximately 2 by 2 feet, or as space permits. They may reduce your sound privacy a bit, so don't rush right into a retrofit without evaluating its impact. A solid, hinged panel or transom in a wall or over a bedroom door could be a solution to possible loss of privacy. An as added benefit, this kind of ventilation will also improve the distribution of solar heat collected in cold weather.

You can also replace fixed windows with ones that are operable or add new windows (on the south) or vents (on the east, west and north). Casement windows are often useful scooping in the wind. Make sure that the casement is hinged on the downwind side of prevailing summer winds.

Opaque vents can usually be installed for somewhat less cost than a window, and they will gain less heat in summer and lose less heat in winter. Standard attic vents can be ganged together to make a larger, weather-resistant, bugproof and secure vent. They should be sealed and insulated in winter to minimize heat loss. Adding a bay window with a horizontal sill vent can provide excellent ventilation that won't be adversely affected by high winds or rain. The sill vent is also less noticeable than vertically mounted ones.

Stack Ventilation

For those who live in low-wind areas, wind is not the only method of natural ventilation. The thermal stack effect can also be used for ventilation cooling if outlet vents are provided up high in a building and inlet vents down low. This stack effect ("thermal chimney") is particularly effective in multi-story houses and can be boosted with a fan.

Typically, the only cooling of this type commonly built into a house is in the attic where vents in the gable allow hot air to escape, drawing in cooler air through soffit vents. If your attic doesn't already have these, consider adding them, and possibly a static or a wind-powered turbine vent as well. Good ventilation can reduce your attic temperature by 20°F (11°C) or more, which lowers the mean radiant temperature of the ceiling facing the living space and makes the area seem cooler.

More involved work like adding ridge vents, a cupola vent, an operable skylight or a roof vent can easily be added when you reroof (using light-colored roofing!), although adding them to an existing roof won't pose excessive difficulties as long as standard sealing and flashing practices are observed. Figure that you'll need to devote about 1 percent of the attic or top floor area to exhaust vent area, with an additional 1 percent of that area used for soffit vents.

Again, no matter what kind of exhaust vents you add that open into living spaces, always provide a tight-fitting insulated panel to close off the unit in cold weather. Winter ventilation of unheated attics should also be maintained to disperse water vapor that could otherwise condense and degrade insulation.

One of the ways to increase thermal stack ventilation is to provide a pathway for air from the cool basement or crawl space into the house, up to the attic and out. This could involve little more than screened, operable vents added in the floor and ceiling in several places, using the same rule of thumb for sizing as with attic ventilation (or 10 square feet each for inlet and outlet vents for a 1000-square-foot house).

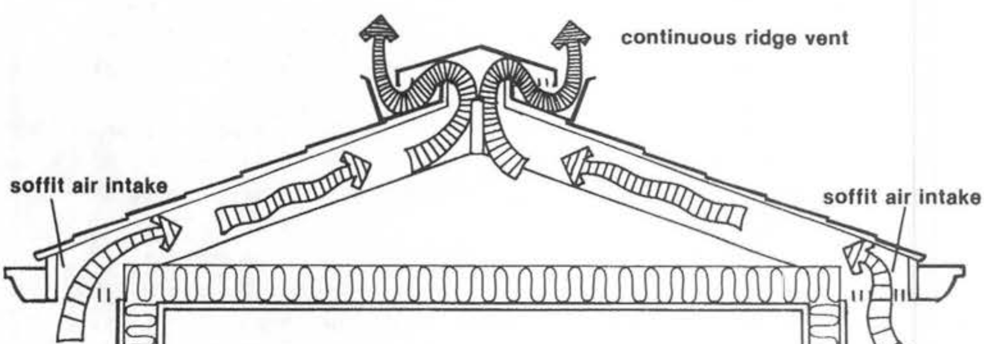

Figure V-7: Continuous ridge ventilation with soffit air intake is the best roof venting system available. As the roof heats up, a convective flow is initiated whereby heated air exhausts through the ridge vent, and cooler air enters through soffit vents.

You can do even more to increase the stack effect by building a solar chimney, such as the one described later in this section. The most basic solar chimney consists of a section of large diameter black pipe (8 inch minimum) extending a few feet up from the roof. For better results make a square chimney with east, west and south glazing and a black-painted north face. A wind-powered turbine vent is a suitable cap for the top. You'll also want an insulated inside shutter to close it off in winter. Again, remember to supply a cool air intake (basement, crawl space) along with a solar chimney. There won't be any benefit in using the stack effect only to pull in hot outside air. (See the project, "A Solar Chimney," later in this section.)

While the solar chimney is a relatively advanced passive cooling technique in as much as it should be preceded by the management techniques and building modifications discussed earlier, it also represents a fairly simple construction project. For even more cooling effect, you can install a "cool tube" to provide the primary air intake of the house. Several types of cool tubes have been built using such things as rectangular clay flue liners, metal culverts and sewer pipe. All of them involve a buried (4 or more feet deep) pipe or array of pipes with an outdoor air intake located in a shaded area. Air entering the house is first drawn through the tube by the flow induced by the solar chimney or a fan. The air is cooled by the earth (which is usually a constant 45 to 60°F, 7–16°C, at these depths), and in some cases it is also dehumidified by the time it enters the house. Although this system has been understood for a long time—similar systems have been used in Persia for thousands of years—experience with them has been gained only recently here in the United States.

One research team, the Princeton Energy Group in Princeton, New Jersey, has made instrumented studies of an actual cool tube made of eight, 40-foot-long, 6-inch diameter plastic pipes buried 4 feet deep. This array provided an average cooling effect of 8700 Btu per hour, equivalent to a small air conditioner. The researchers estimate that in an energy-efficient house of 2300 square feet, this cool tube array could meet 70 percent of the building's cooling load.[8]

This notion of coupling a cool air intake with a solar-driven exhaust can be applied to other solar space heating retrofits that serve as the exhaust driver. Consider the mass wall glazing retrofit used for passive space heating: It heats up in the summer by absorbing high-angle direct radiation and must be built with some venting capability to dump the unwanted heat to the outside. That of course implies a convective flow, and if the wall isn't heavily shaded in the summer, it may well be a solar chimney in disguise. So too might a vertical-wall air heating collector be the beginning of your natural cooling system. All of this speaks for advance planning that considers both a house's heating and cooling needs.

Before you invest your time and energy in solar chimneys and cool tubes, you should first consider using a little electricity to power one or more exhaust fans used in conjunction with added floor, wall and ceiling vents. Because air flow is forced, the fan option may work better than the more involved and subtle passive cooling effect. Fans do, however, use a fair amount of electrical power (though much less than air conditioners), an increasingly important consideration for the energy-conscious 80s.

Forced Ventilation

Forced-air cooling is at its simplest with a small fan pointed right at you. Increasing air flow past your body evaporates perspiration from your skin and keeps you feeling cooler. Portable fans can also be used to increase nighttime ventilation and cooling of a house. Place the fan so it will draw cool air into the rooms where you are sleeping.

One step beyond the portable fan is a "Casablanca" fan hanging from the ceiling. It can be used to help keep you cool (evaporatively) and to ventilate the house in summer, and it will also help mix the air for more uniform heating in the winter. Some models use only 40 watts on low speed. In the not-too-distant future, photovoltaic cells will be cheap enough to warrant their use in powering fans and other appliances. What a perfect combination: using solar electric power to remove excess solar heat.

For an even more powerful cooling system, consider a whole-house fan. The fan is installed in the ceiling to suck air out of the house and blow it out the attic vents, allowing cooler air to enter from a basement, crawl space or shaded side of the house. Such fans also play a role in increasing evaporation from your skin. The approximate capacity needed is indicated in table V-5. They can be thermostatically controlled to turn on when ambient temperature and humidity drop low enough and can be used with furnace filters placed in windows to reduce the amount of dust and pollen brought into the house. Whole-house fans are helpful and cost-effective even when used in conjunction with an air conditioner, in which case they should be set to kick on when the air conditioner goes off.

Moved-In Mass: the Coolth Connection

In many areas ventilation (up to a whole-house fan) with solar control will provide night comfort and daytime cooling for much of the summer, but for better cooling in an area with consistently high day and low night temperatures (and low humidity), added thermal storage may be helpful. Just as thermal mass stores solar heat for winter night heating, it can store the coolth of the night for use during a hot summer day. Night ventilation with cool air removes heat from the thermal mass by radiation and convection. The cool mass then acts as a sink for radiation from warm people and other internal heat sources during the day.

Thermal mass for nighttime cooling is most effective when it's widely distributed through wall, ceiling and floors, i.e., lots of surface area, because the heat exchange rate is fairly slow between air and mass. This contrasts with winter heating, when mass is most effective if it is directly in front of the south windows, where the concentrated solar radiation promotes more rapid heat exchange. You should definitely consider water storage over masonry for a retrofit with a limited area for thermal mass. "Moved-In Mass" in Section III-D describes in more detail some techniques and considerations for adding thermal mass.

Still more powerful natural cooling systems can be developed utilizing the effects of water evaporation and night sky radiation, or the seasonal storage of coolth in the form of ice or cold water. The most effective systems for retrofitting, and they are

TABLE V-5 RECOMMENDED FAN CAPACITIES

Floor Area of House (ft^2)	Amount of Air Fan Should Deliver (ft^3/min) Cool Night Regions	Warm Night Regions
800	3000	6500
1000	4000	8000
1200	5000	9500
1400	5500	11,000
1600	6400	13,000
1800	7000	14,500

SOURCE: L.W. Neubauer and H. Walker, *Farm Building Design* (Englewood Cliffs, N.J.: Prentice-Hall, 1961).
NOTE: Table is based on air exchange rate of 1 air change per minute in warm nights, ½ air change per minute in cool night areas.

by no means simple retrofits, are those that combine evaporation and night sky radiation. An introduction to evaporative cooling and night sky radiation will help clarify how these systems work and how you might use them to help cool your house.

Evaporation

The evaporation of water can have a very powerful cooling effect, as you know from stepping out of a swimming pool on a windy day. The phase change from water to water vapor absorbs a great deal of heat (1000 Btu per pound of water evaporated). Evaporating a cubic foot of water will provide fully 60,000 Btu of cooling, a considerable amount indeed. With reasonably good air flow across the water surface, a small pond can evaporate 10 to 15 inches a month, a cooling rate of over 2000 Btu per square foot per day, or about 85 Btu per square foot per hour. A 500-square-foot section equipped with sprinklers for evaporative cooling can remove heat at the rate of over 40,000 Btu per hour. Roof sprinkling is a common application of evaporative cooling for reducing roof temperature. Wetting down roofs for cooling has long been used to cool and protect the flat, tarred roofs of commercial buildings, and the same technique can be used on houses to lower the temperature of the roofing material by as much as 30 to 40°F (17–22°C), which helps to reduce attic air temperatures by up to 25°F (14°C). Naturally, a cooler attic helps to maintain a cooler living space, especially in houses that have little attic insulation. A house with a well-insulated roof or attic floor will not gain maximum benefit from this technique, but nevertheless heat gain through the insulation will be somewhat reduced. See the box "Cool Roofs" in this essay, which describes a commercially available residential roof sprinkling system.

Night Sky Radiation

The effectiveness of night sky radiation depends on clarity of the night sky, low humidity and an air temperature drop of at least 20°F (11°C) from day to night. With these conditions, the cool night sky acts as an infinite heat sink for radiation from roofs and walls. The rapid chilling in the desert after a hot day results from night sky, radiative cooling. Even in more humid areas, cooling rates up to 50 percent of those in low-humidity areas are possible, which means that up to 200 Btu per square foot per day of cooling effect could occur on a clear night. Radiant cooling is definitely more effective in the drier areas of the United States, but combined with evaporation or with ventilation, it can be worthwhile elsewhere. Refer back to figure V-1 to see where in the United States night sky cooling will be most effective.

Work in Israel on night sky cooling has produced a system that may be applicable for some retrofits. This "Negev Desert" design features a second layer of roofing over the house's original roof. The white-painted sheet-metal roof is raised to form a plenum or airspace between it and the original roof so that as the metal cools at night, the plenum air is cooled and flows down through vents that open into the house.[9]

Combined Cooling Systems

Other more exotic cooling systems that use the combined effects of evaporation and night sky radiation are the roof pond, the cool pool and a heat exchanger coupled to a large body of water such as a swimming pool. All three options typically involve major modifications.

The roof pond involves building a metal roof support system that doubles as a ceiling for the room below and provides an excellent medium for radiant transfer. The ceiling supports an array of open water tanks or closed water bags that are in turn covered with an operable, insulated hatch-cover system. The roof insulation panels are drawn back at night to initiate cooling by night sky radiation, and if the water is not contained, by evaporation as well. The roof pond can also be used for heating by reversing the operation. The panels are open during the day to collect solar heat and closed at night; the heat radiates into the room through the ceiling. The cool pool concept is meant to be used just for cooling.

A more specialized cooling technique using evaporation and night sky radiation may prove useful for homes built on hot-water heated radiant slabs, where the coolth of an unheated swimming pool, pond or stream can be tapped. Pumping and filtering cool water through the slab keeps its temperature down and can provide sufficient cooling for the entire house by drawing room heat down to it and "flushing" the heat away via the circulating water.

Such a slab could also be cooled with water from a properly designed liquid flat plate collector that is run at night in the summer. It is best that the collector array be unglazed, e.g., a swimming pool heater, to allow adequate radiation to the night sky —since glass and some plastics are opaque to infrared radiation. Some plastic glazings, however, do not block infrared and may be suitable for a heating/cooling collector.

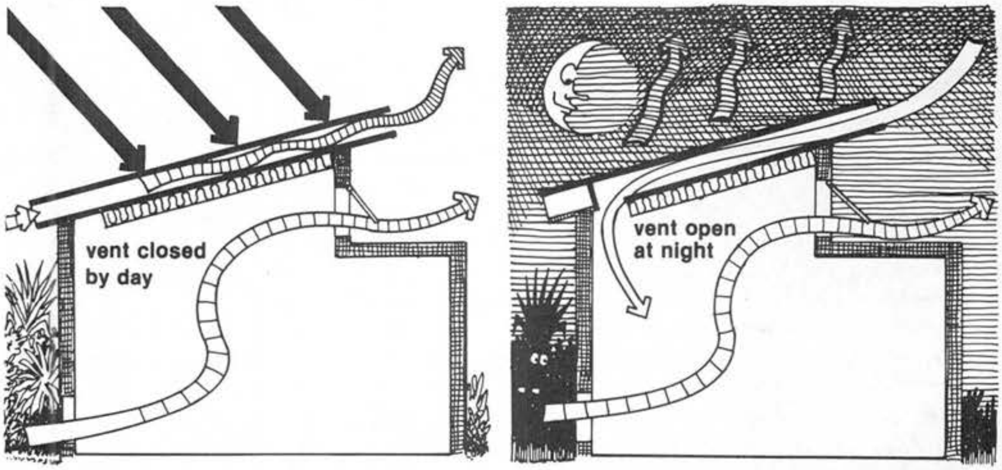

Figure V-8: The double roof helps with cooling both day and night. By day it works like a ridge vent system with soffit air intake, dumping heat buildup back to the atmosphere. At night the metal outer roof rapidly radiates heat to the night sky, and as the air between the two roofs cools, the cooled air is allowed to fall into the house.

Make an experiment out of it: Pump water through your collectors on a clear summer night and see what the temperature difference is from inlet to outlet. If the flow rate is 2 to 3 gallons per minute and the water temperature drops, say 5°F (3°C), the collectors are dumping 5000 to 7000 Btu per hour into the atmosphere, and it's taking those Btu's from the slab. That's a good bit of cooling when you consider that standard room air conditioners are sized to extract 5000 Btu per hour from 150-square-foot rooms and 10,000 Btu per hour from 300-square-foot rooms.[10]

Air heating collectors may also work for nighttime cooling if they are designed properly. Again, plastic glazing is more effective at radiating heat than glass, so consider summer cooling when you choose the glazing for an air heating collector. You will also want to include more mechanical and electronic controls, possibly reversing fans to allow the system to pull hot air away from high ceilings and return cooled air at floor level. An integrated system could provide both heating and cooling with no great increase in cost, but you'll do well to consult with a contractor experienced in solar design for such a dual-function system.

Evaporative Coolers and Air Conditioners

If the techniques we've discussed don't provide all the cooling you need, or if you're not ready to make major house modifications, you have the option of using a mechanical cooling system to make your house as cool as you'd like. There are products available that operate somewhat more efficiently than do their predecessors, and these

(continued on page 608)

Cool Roofs

A roof spray evaporative cooling system that helps keep a lid on roof temperature buildup is available for residential use from Spraycool, Inc., 890 Atlanta Street, Roswell, Georgia 30075. Telephone: (404) 922-4957. In this system, small amounts of water are sprayed onto the roof at timed and thermostatically controlled intervals. Heat is absorbed from the roof and dispersed into the atmosphere as the water changes from liquid to vapor. Spraycool claims this system can get rid of more than 90 percent of the solar heat absorbed by a roof, which can result in a 25 percent or greater reduction in a house's cooling load.

In summer roof and attic temperature can reach as high as 170°F (77°C), but if this heat buildup can be substantially limited, the amount of heat that can radiate down to living areas is also reduced. Although insulation slows the transfer of heat through a roof, it doesn't stop it. In fact, it is much harder to get rid of heat that has penetrated insulation, and this, according to the manufacturer, is why the system is useful even with insulated roofs. An additional benefit of keeping the roof cool is that lower temperatures can prolong the life of asphalt-based and other synthetic roofing materials.

In a typical residential installation, specially perforated PVC pipe is connected to a cold water supply and mounted along the roof ridge. In most cases, standard house water pressure is adequate for spraying. The controls for the system include a solenoid valve, a thermostat with a sensing element implanted on the roof and a timer that controls the spray intervals. The controls are usually set to keep the roof from getting above 90°F (32°C). When a temperature sensor signals the control panel that the roof tempera-

Photo V-7: Talk about unusual, a roof spray system in action is certainly a unique sight, but it may well become standard equipment for roofs in the not too distant future.

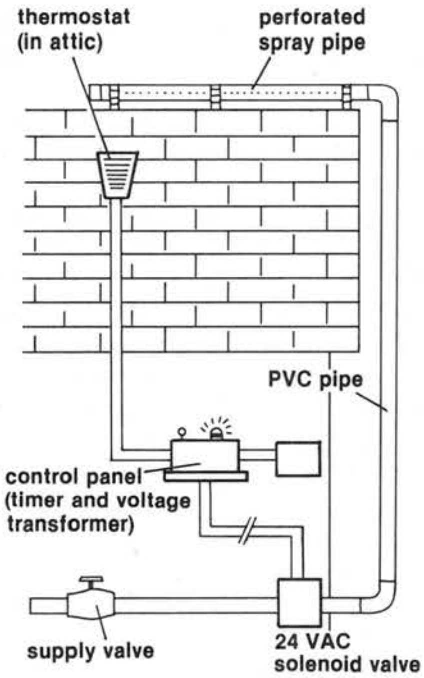

Figure V-9

ture is over 90°F, the solenoid valve opens, and the pipe system sprays a mist of water onto the roof. The system shuts off after 10 to 15 seconds and will come on again in about 10 minutes if the roof temperature rises over 90°F. The fine spray thoroughly wets the roof, but the system is sized so there isn't any excessive runoff or dripping.

In most residential applications, a single-zone system will cool the roof, but larger homes might require multiple zones. Spraycool is suitable for any type of roof and for any type of home including mobile homes, which may benefit from spray cooling more than most houses because they are usually such poorly insulated, metal-skinned hot boxes. Seasonal shutdown of the system simply involves turning it off and draining it in the fall to prevent freezing, and flushing it and turning it back on in the spring.

The amount of electricity needed to operate the system is negligible. Water consumption is also low. Commercial installations operating for a 10-hour day use between 1/5 and 1/10 of a gallon of water per square foot of roof per day, and residential systems generally use less. Water use will vary according to the size of the roof, the climate and the water pressure, but to determine roughly how much water a Spraycool system would use in your house, take a container and put it under the tap; turn it on full force for about 12 seconds, measure the volume and multiply by six to determine the amount of water that would probably be used in one hour (six spray cycles per hour). On the hottest summer days, the system will operate for up to about 10 hours (60 spray cycles), while on cooler days there will be fewer cycles.

Cooling energy savings will of course vary widely too. When a gallon of water evaporates from the roof, it takes about 8000 Btu with it, but that doesn't translate directly into an interior cooling effect. The Spraycool company claims that a 25 percent reduction in cooling load is possible. A big plus is that Spraycool, which is the only company offering a residential scale system, will put together custom-designed kits for do-it-yourselfers.

Margaret J. Balitas

are the ones to choose. There are two basic types of mechanical systems for adding cooling: the evaporative cooler and of course the air conditioner.

The evaporative cooler is the most efficient of the two, delivering in most cases comparable cooling capacity for one-quarter to one-half the energy cost of an air conditioner. There are two basic types. The direct evaporative cooler or "swamp cooler" draws outside air through wetted pads and blows the cooled air through the house. In recent years, the "swamp cooler" has been ignored in favor of the air conditioner, but it is effective, particularly in drier climates where the added humidity won't be a problem.

The second type is the indirect evaporative cooler. It is a direct evaporative cooler coupled to a heat exchanger. Typically, it draws air from the house through evaporative pads and through a heat exchanger, exhausting the warmed, humid air to the atmosphere. A second fan draws dry exterior air through a filter and through the heat exchanger, where it is cooled off and blown into the house. This is less efficient than a direct evaporative cooler, but it doesn't add humidity to the living space. It appears that this type of evaporative cooler has fallen out of production, but a system could be built by a skilled do-it-yourselfer.

In areas that are not very hot but where high humidity keeps indoor conditions out of the comfort range, a dehumidifier may be useful. A dehumidifier does use less energy than an air conditioner and can dry air out enough to cool by helping to increase evaporation from your skin, but in most cases an air conditioner is better, dehumidifying while it lowers air temperature.

Air Conditioners

Where temperatures remain high through the night or where, as in the Southeast, high humidity is consistently linked with high ambient temperatures, air conditioners may prove indispensable. Choosing an efficient air conditioner is vitally important, whether it's a first-time purchase or the replacement for an old clunker. Air conditioner efficiency is nowadays described by the Energy Efficiency Ratio (EER)—simply the unit's Btu rating (how quickly it removes heat) divided by its wattage. Thus the higher the EER, the less the unit will cost to operate. EERs for air conditioners range from 5 to over 11, and a unit rated at 10 is twice as efficient as one rated at 5, using half the electrical power to achieve the same cooling effect. Don't buy an air conditioner with less than an EER of 8 to 10. Even though the lower initial price of a less efficient unit may seem like a bargain, it isn't. The higher cost of an EER 10 air conditioner will be recouped with energy savings in the first two or three years of operation.

Air conditioners are of two basic types: air to air and air to fluid. Both are specialized, one-way heat pumps that move interior heat to the outside. Air-to-air heat pumps, the standard air conditioner, can achieve up to a 20 to 30°F (11–17°C) temperature difference between indoor and outdoor air, but the hotter it gets, the tougher is the job of cooling. So air conditioners are limited to achieving interior air temperatures in the 80s on days when the ambient air temperature goes over 100°F (38°C).

Water-to-air heat pumps are not standard items. They are designed to use cool source water circulated from a well, a swimming pool or from coils sunk in the earth. The temperature of the water from these sources is usually lower than the average summertime air temperature, perhaps 50°F (28°C) lower. So it's not hard to see that a water-to-air unit can be much more efficient than an air-to-air unit in dealing with summer heat. These special air conditioners are available from several reputable manufacturers. They will require access to a well, a lake or pond, a creek or a swimming pool.

Along with built-in efficiency, an air conditioner should be closely matched to the cooling load for best operating efficiency. If often happens that tradespeople size air conditioners using rather generous rules of thumb, figuring it is safer to oversize than undersize. This can result in an air conditioner that is 50 percent or more too large, particularly when installed in an energy-efficient house. You can assume that after applying as many solar control and ventilation cooling methods as possible, your house's cooling load will be cut by fully 25 to 75 percent.

Ideally, the unit should be on the north of the house or on a side with lots of shade. Failing that, it should be fully shaded with a canvas awning or wood shade, though you must be careful not to impede the unit's warm air exhaust with an add-on overhang. A window-mounted unit should be tightly sealed within the window frame to prevent any infiltration of outside air. With central air conditioning systems, check that ducts are sealed and insulated to make sure the cool air gets to you.

You can minimize energy use by keeping the air conditioner off when no one is home—it is cheaper to cool off the house starting one-half hour before you get home (by using a timer control) than cooling all day long. Also try to zone the house so you only cool the areas that really need to be cooled. You can also save by coupling the air conditioner to the whole-house fan so that the air conditioner goes off as soon as the outside temperature has dropped enough for effective ventilation cooling. Keep the thermostat at 78°F (26°C) or higher; every degree Fahrenheit that you lower the thermostat may add as much as 3 to 4 percent to your cooling bill. Keep the air conditioner

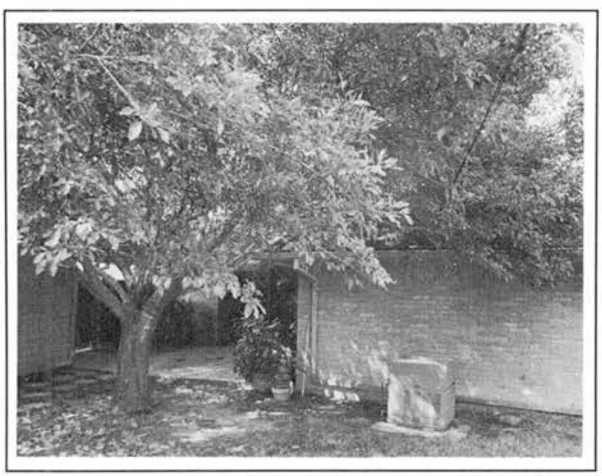

Photo V-8: The best place for an air conditioner is on the shaded side of a house. The unit is working to dump heat from the house via its exterior condenser, and if it's exposed to direct sunlight, it makes the task somewhat more difficult, reducing the efficiency of the operation.

in good condition. It's particularly important to keep the air filter and cooling coils clean.

If you think of them as cars, air conditioners can be gas guzzlers, or they can be Volkswagens, depending on the kind of unit you buy and how you use it. But better yet, transform your home into a summertime Volkswagen by implementing some of the techniques described in this essay and perhaps doing away with the need for any air conditioner at all. If we need to automatically flip on the air conditioner at the slightest threat of a hot day, then we're living by habits that work against the usefulness of overhangs, shade screens, improved ventilation and the like. Air conditioning without air conditioners is about modifying our habits as well as our homes, and the "coolest" success is in harmonizing the two.

David Bainbridge

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Hardware Focus

Attic Fans

Broan Manufacturing Co.
Hartford, WI 53027
(414) 673-4340

Broan Powered Attic Ventilators
Roof-mounted attic fan; thermostat is set at 100°F (38°C); models range from 930 to 1600 cfm.

Penn Ventilator Co., Inc.
Red Lion and Gantry Rds.
Philadelphia, PA 19115
(215) 464-8900

Breezecap Venter
Roof-mounted attic fan; thermostat is set at 95°F (35°C); 1310 cfm.

Evaporative Coolers

Evaporative coolers are relatively inexpensive to install and operate, but they are not suitable for every geographical area. They are generally not recommended for homes near the seashore or in other areas of high humidity.

Essick Manufacturing Company (see below) has a booklet entitled *Evaporative Air Cooling Handbook: A Manual for Contractors, Engineers and Architects* that is helpful in assessing the capabilities and limitations of evaporative coolers.

The companies listed below manufacture a variety of coolers. The range of sizes is indicated by listing the models with the lowest and highest cfm.

Champion Cooler Corp.
P. O. Box 886
1724 S. Scullie
Denison, TX 75020
(214) 465-1962

16 models. 2800 to 6500 cfm. 2-speed motor.

Dearborn Stove Co.
P. O. Box 28426
3000 W. Kingsley
Dallas, TX 75238
(214) 278-6161

6 models. 2400 to 4800 cfm. 1 or 2-speed motor.

Essick Manufacturing Co.
3215 Brown St.
Little Rock, AR 72204
(501) 372-7722

48 models. 2200 to 16,000. 1 or 2-speed motor.

Goettl Air Conditioning, Inc. 2005 E. Indian School Rd. Phoenix, AZ 85016 (602) 957-9800	15 models. 3300 to 21,000. 1 or 2-speed motor.
Health Aire Corp. 27465 Pacific Ave. Highland, CA 92346 (714) 862-0281	**CemGlass Cooling System** Fiberglass construction. 4000 cfm. 2-speed motor.
McGraw-Edison Co. International Metal Products Division P. O. Box 20188 500 S. 15th St. Phoenix, AZ 85036	2 models. 4000 or 4500 cfm. 2-speed motor.
Phoenix Manufacturing, Inc. 415 S. Seventh St. Phoenix, AZ 85036 (602) 258-8483	14 residential models. 2000/1330 to 6500/4330 cfm. 1 or 2-speed motor.
Space-Aire Co. 169 N. Main St. Lake Elsinore, CA 92330 (714) 674-1144	**Space-Aire** 3 models. 3000, 4400 or 5500 cfm. 2-speed motor.
United Electric Co. P. O. Box 5148 500 Block Kell Blvd. Wichita Falls, TX 76307 (817) 767-8333	9 models. 3000 to 5500 cfm. 1, 2 or 4-speed motor.
Williams Furnace Co. 14960 Firestone Blvd. La Mirada, CA 90638 (714) 521-6500	12 models. 3200/2135 to 6500/4335 cfm. 1 or 2-speed motor.

Reflective Fabrics for Shades and Curtains

Duracote Corp. 350 N. Diamond St. Ravenna, OH 44266 (216) 296-3486	**Foylon 7001 & 7018** Drapery liner material. Foil on lightweight nylon scrim. 54″ wide; 100 yds per roll. **Foylon Durashade 4413** Aluminum foil on one side, white vinyl fabric on other side. Designed for use in shades. 36″, 45″ or 54″ wide; 60 yds per roll. **Foylon 7137** Aluminum foil on one side, black vinyl on other side. For use in greenhouse covers. 54″ wide; 200 yds per roll.

King-Seeley Thermos Co.
Metallized Products Division
37 East St.
Winchester, MA 01890
(617) 729-8300

Astrolon
One layer of 0.00125 aluminized colored polyethylene and 1 layer of 0.00125 aluminized clear polyethylene, with both metal surfaces bonded to a glass scrim and embossed.

Roof Vents

HC Products
P. O. Box 68
Princeville, IL 61559
(309) 385-4323

Vent-a-System
Consists of Vent-a-Ridge, a continuous louvered opening along the peak of a roof that lets warm air escape from the attic, and Vent-a-Strip, continuous intake vents along the soffits parallel to the ridge. This is the most effective roof ventilation system currently available.

Sun Control Shades

The shading coefficients listed below are those claimed by the manufacturers on their product literature. Clear glass has a shading coefficient of 1.0. A shading coefficient of 0.25 means that 75 percent of the incident solar energy is rejected. Shading coefficients should be used as one guide to selecting shades. The shades listed below are for interior application unless indicated otherwise.

Joel Berman Associates, Inc.
102 Prince St.
New York, NY 10012
(212) 226-2050

MechoShade
Electro Shade
Roller shades; woven vinyl fabrics with varying degrees of openness; shades are single-layer, 2-layer or 2-layer with reflective film; shading coefficients range from 0.25 to 0.69 for various models and colors.

Gila River Products
6615 W. Boston St.
Chandler, AZ 85224
(602) 961-1244

Gila Insulating Shade
Roller shade; transparent polyester film with bronze-colored tint; shading coefficient: 0.33; 36", 42" or 48" shade mounts or custom sizes; side tracks are optional.

The Moore Co.
Marceline, MO 64658
(816) 376-3583

Moore Solarshades
Exterior operable, louvered aluminum shades; widths from 8′ to 14′; primarily for commercial applications, but suitable for window walls, greenhouses, etc.; shading coefficient: 0.2.

MRS Interior Systems, Inc.
100 Marcus Dr.
Melville, NY 11747
(212) 895-4788

Prima Rolling Shade System
Motortex
Interior or exterior roller shades; manual or motorized controls; available in a variety of colors; shading coefficients range from 0.16 to 0.47 (for exterior applications).

The Plastic Sun Shade Co., Inc.
389–91 Union Ave.
Irvington, NJ 07111
(201) 373-8181

Sun Shades
Roller shades; acetate or Mylar; custom sizes; shading coefficients range from 0.16 to 0.51 depending on color; 8 colors; UV resistant.

Solar Screen Co.
53–11 105th St.
Corona, NY 11368
(212) 592-8223

Kool Vue Window Shades
One layer of metallized Mylar between 2 layers of mylar; roll-down shade; custom sizes; colors and shading coefficients: bronze (0.38), gold (0.25), gray (0.36), silver (0.27).

Sol-R-Veil, Inc.
60 W. 18th St.
New York, NY 10011
(212) 924-7200

Sol-R-Veil
Roller shade; vinyl-coated fiberglass yarn; 60 sizes; smallest: 36″(H) × 18″(W); largest: 144″(H) × 100″(W); shading coefficients and colors: white (0.37 or 0.48), bronze (0.69), brown (0.74), for interior application; white (0.21), bronze (0.19), beige (0.21), gray (0.12), for exterior application.

J. P. Stevens
P. O. Box 1138
Walterboro, SC 29488
(803) 538-8045

Comfort Shade
Vinyl-coated fiberglass woven with rib in horizontal direction; colors and shading coefficients: white (0.62), gray (0.35), charcoal (0.37), bronze (0.35), bone (0.50); UV resistant.

Sun Control Products, Inc.
431 Fourth Ave. S. E.
Rochester, MN 55901
(507) 282-2778

NRG Window Shade
Roller shade on side tracks; aluminized polyester; colors and shading coefficients: charcoal/silver (0.15), bronze/silver (0.28); UV resistant; custom sizes.

Wind-N-Sun Shield, Inc.
P. O. Box 2504
131 Tomahawk Dr.
Indian Harbor Beach, FL 32937
(305) 777-3558

Wind-N-Sun Shield
Drapery liner panels or roller shades. Aluminized polyester on one side. White vinyl on other. Shading coefficient: 0.01; UV resistant; sizes: 37¼″ × 4′, 55¼″ × 6′; custom sizes.

Sun Control Films

Sun control films adhere to inner surfaces of windows to limit direct gain. The films are usually two or three layers of laminates made of metallized (reflective), transparent and/or tinted layers.

Dunmore Corp.
Newtown Industrial Commons
Penns Trail
Newtown, PA 18940
(215) 968-4774

Dun Ray
Adhesive; metallized clear polyester film; silver; shading coefficient: 0.24; sold in rolls 36″ or 48″ × 25′; UV resistant.

Gila River Products
6615 W. Boston St.
Chandler, AZ 85224
(602) 961-1244

Insul Film
Laminated polyester sheets; adhesive; reflective colors and shading coefficients: silver (0.30), gray (0.39), bronze (0.39), gold (0.38); UV resistant.

Madico
64 Industrial Parkway
Woburn, MA 01801
(617) 935-7850

Reflecto-Shield
Adhesive; aluminum within polyester laminate; colors and shading coefficients: gray (0.25, 0.36), gold (0.24, 0.30), bronze (0.25, 0.36), silver (0.26, 0.31); UV resistant; sold in rolls 60″ × 100′ or in kits with precut sizes.

Martin Processing, Inc.
P. O. Box 5068
Martinsville, VA 24112
(703) 629-1711

LLumar
Adhesive; metallized polyester laminate; colors and shading coefficients: silver (0.28), bronze (0.31), gray (0.30), gold (0.27); UV resistant.

Metallized Products
2544 Terminal Dr. S.
St. Petersburg, FL 33712
(813) 822-9621

Sun-Gard Window Films
Three polymer layers and 2 film layers; adhesive; colors and shading coefficients: silver (0.24), bronze (0.38), gray (0.36), gold (0.25), transparent silver (0.55); UV resistant; 9 precut sizes for do-it-yourselfers; also rolls of 100′ and 200′.

National Metallizing
P. O. Box 5202
Princeton, NJ 08540
(609) 443-5000

Nunsun
Two layers of polyester film with a layer of aluminum; adhesive; colors: bronze, gold, gray, silver; shading coefficients range from 0.20 to 0.49; UV resistant.

Plastic-View Transparent Shades, Inc.
P. O. Box 25
15468 Cabrito Rd.
Van Nuys, CA 91408
(213) 786-2801

Plastic-View's Film-to-Glass
Two sheets of film with middle sheet aluminized; adhesive; colors and shading coefficients: gold/silver (0.25), gray/silver (0.36), silver/silver (0.27), bronze/silver (0.38), bronze/bronze (0.47), gold/gold (0.30), gray/gray (0.43); UV resistant; prepackaged sizes: 5′ × 2′, 3′, 4′ or 8′; roll form: 5′ × lineal ft.

Solar Screen Co.
53–11 105th St.
Corona, NY 11368
(212) 592-8223

E-Z Bond
One layer of aluminum between 2 layers of film; adhesive; colors and shading coefficients: bronze (0.38), gold (0.25), gray (0.36), silver (0.27); UV resistant; kit form: 20″, 40″, 60″ widths; 5′, 10′ lengths; roll form: 60″ × 25′; 24″, 40″ or 60″ × 100′.

Solar-X Corp.
25 Needham St.
Newton, MA 02161
(617) 244-8686

Solar-X
Clear film with coating of Transolume metal; adhesive; colors: bronze/silver, silver, smoke/silver, gold/silver; shading coefficient: 0.24; UV resistant; sizes available: 18″ × 72″, 36″ × 78″, 48″ × 78″, 54″ × 78″.

Sun Control Products, Inc.
431 Fourth Ave. S. E.
Rochester, MN 55901
(507) 282-2778

Sun Control Film
Aluminized polyester; adhesive; colors and shading coefficients: silver (0.20), bronze (0.35), gold (0.26); UV resistant; custom-cut sizes; widest: 60″.

3M Co.
St. Paul, MN 55101
(612) 733-1110

Scotchtint P-19 Window Insulation Film
Adhesive; color: gray; shading coefficient: 0.23; UV resistant.

Vacumet Corp.
20 Edison Dr.
Wayne, NJ 07470
(201) 628-0400

The Eliminator
Adhesive; colors: silver and brown; shading coefficient: 0.25; do-it-yourself sizes: widths 14", 34", 48" and lengths 78", 156"; professional lengths up to 60" wide.

Sun Control Screens, Blinds and Shutters

The shading coefficients listed below are those claimed by the manufacturers on their product literature.

Hamel, Inc.
999 Airport Rd.
Lakewood, NJ 08701
(201) 367-7670

Haroscreen
Exterior roll-down screen; fabric or open-weave PVC-coated fiberglass; custom sizes; shading coefficient: 0.16; UV resistant.

Kaiser Aluminum
300 Lakeside Dr.
Oakland, CA 94643
(415) 271-3321

ShadeScreen
Exterior screens; louvered aluminum; colors and shading coefficients at 10° or 40° profile angle: green (0.411, 0.195); black (0.429, 0.139); widths 18" to 48"; 50' per roll.

KoolShade Corp.
P. O. Box 210
722 Genevieve St.
Solana Beach, CA 92075
(714) 755-5126

KoolShade Solar Screen
Exterior screens with small woven bronze louvers; aluminum frame; widths up to 72½"; standard color: black; shading coefficients: Standard KoolShade (0.232); Low Sun Angle KoolShade (0.15).

Joseph C. Maillard Enterprises
1233 E. Ramsey St.
Banning, CA 92220
(714) 849-3141

Faber Maximatic, Faber Solarmatic
Exterior aluminum louvers; maximum widths 13' × 13'; cord, rod or motorized controls depending on size; shading coefficient: 0.1. Expensive.

MRS Interior Systems, Inc.
100 Marcus Dr.
Melville, NY 11747
(212) 895-4788

Sundrape Vertical Blind System
Interior blinds with vertical louvers; available in various fabrics and widths; motorized system available with sun sensing devices; shading coefficients range from 0.39 to 0.74.

Nichols-Homeshield, Inc.
1000 Harvester
W. Chicago, IL 60185
(312) 231-5600 or (205) 345-2120

Nichols-Homeshield Blinds
Exterior aluminum louvers; custom sizes; shading coefficient: 0.17; numerous neutral colors.

Pease Co.
Ever-Strait Division
7100 Dixie Highway
Fairfield, OH 45023
(513) 867-3333

Pease Rolling Shutter V or VM
Exterior shutter of hollow PVC slats; motor-operated; rolls down on track; R-values when installed 1¾" outside single glazing: Model VM, R-1.76; Model V, R-2.47. Sizes to customer's specifications; UV resistant; shading coefficient: 0.1.

Phifer Wire Products, Inc.
P. O. Box 1700
Tuscaloosa, AL 35401
Toll-free number: (800) 633-5955

SunScreen
Exterior screens; woven fiberglass; brown; sold by rolls: 28" × 76", 32" × 76", 36" × 84", 48" × 84"; shading coefficient: 0.32. UV resistant.

The Rolsekur Corp.
Fowler's Mill Rd.
Tamworth, NH 03886
(603) 323-8834

Rolsekur Rolling Shutter
Exterior shutter of interlocking PVC extrusions or wood profiles; shutter manually or motor-operated from inside; UV resistant; custom sizes; shading coefficient: 0.1.

Sears, Roebuck and Co.

The Sears catalog lists a variety of sun control products.

Serrande of Italy
P. O. Box 1034
West Sacramento, CA 95691
(916) 371-6960

Serrande Shutter
Exterior shutter of PVC or wood; all slats are ½" thick with reinforced steel; no limit to span; custom sizes; manually or motor-operated; shading coefficient: 0.1.

J. P. Stevens
P. O. Box 1138
Walterboro, SC 29488
(803) 538-8045

Comfort Screen
Interior or exterior applications; vinyl-coated fiberglass woven with rib in vertical direction; colors and shading coefficients: white (0.62), gray (0.35), charcoal (0.37), bronze (0.35), bone (0.50); UV resistant; widths up to 84".

Virginia Iron & Metal Co.
P. O. Box 8229
Richmond, VA 23226
(804) 266-9638

Vimco Solar Shield
Exterior screens; woven fiberglass fabric; gray; shading coefficient: 0.33 (45° profile angle); widths 29", 33", 37", 49"; heights to 80"; UV resistant; can be rolled up and stored at head of window.

Turbine Vents

Penn Ventilator Co., Inc.
Red Lion & Gantry Rds.
Philadelphia, PA 19115
(215) 464-8900

Turbine Ventilators
Diameters range from 6" to 30".

Triangle Engineering Co.
P. O. Drawer 38271
Houston, TX 77088
(713) 445-4251

Wisper Cool
Turbine sizes: 12" or 14" diameters.

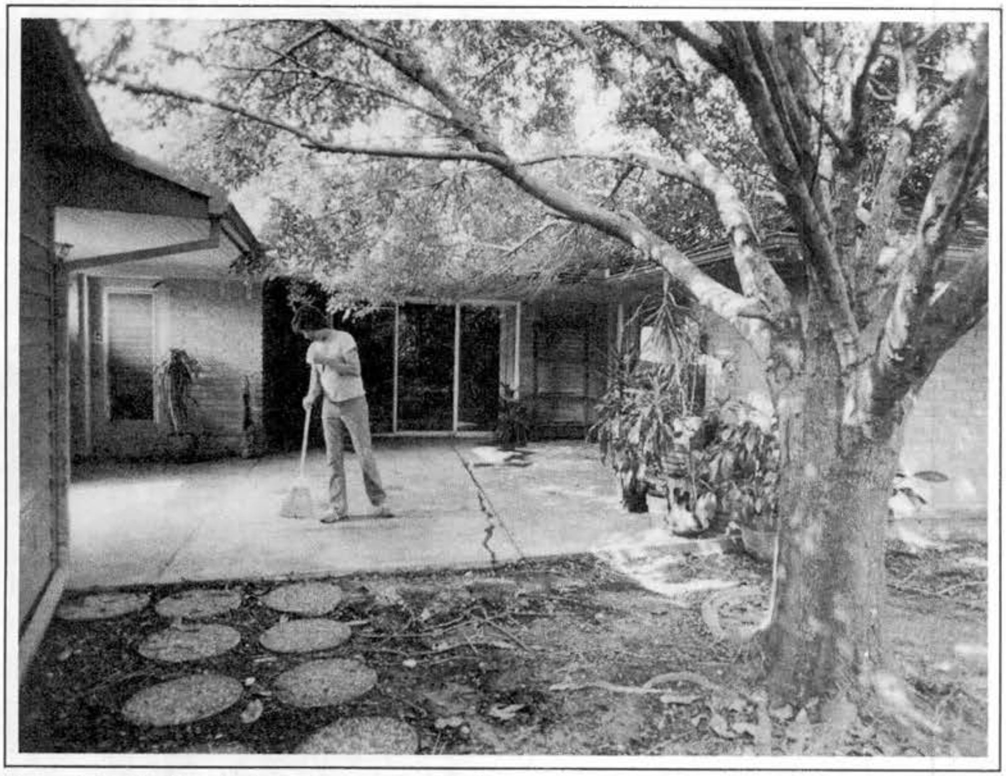

Photo V-9: Shade, shade and more shade: This was a primary aim in the retrofit work at the Houston House. It makes both the inside and the outside more comfortable through the hot Texas summer.